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Consideration of risk management in global production footprint design

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Abstract

The proceeding globalization leads to growing and more and more complex company networks. Especially for the production industry the high cost pressure forces companies to spread their production sites over the globe. Low labour costs, distances to potential markets and productivity influences lead onto complex decision situations for managers in charge. Beside the total landed costs to produce the product portfolio, the global footprint decisions are influenced by other dimensions as well. Since it was possible to improve global footprint design decisions by an evolutionary algorithm with the web tool OptiWo, this paper specifies an approach to quantitatively implement risk management as the second dimension of these decisions. With the distribution of production sites over the globe the companies are getting more and more exposed to different potential global risks. Additionally, the actual political situation of crisis around the world as well as geological disasters stroked the fears of losses. Finally risk-averse companies try to get an analysis on political and geographical risks for the particular footprint they are designing. The approach consists of two basic elements of a typical risk analysis: Firstly, the risk as the feasibility of a political or geological event causing a production blackout in a site is rated for every site. This risk rating is generated by professionals in this specific field. Secondly, the impact of a blackout of a specific site of a network has to be rated. Finally, these two risk dimensions are combined to get a specific footprint risk level. The approach is standardized to allow an integration into the existing tool to make the risk analysis of a global production network efficient and automatically useable. Due to this achievement managers are able to overview another dimension of global footprint design decisions efficiently. A validation of our approach is presented using a data set of a recently conducted industry project. Different network scenarios of a global manufacturer in the automation industry are compared to point out different characteristics of global footprint risks.

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1. Introduction and Motivation

1.1. Introduction

Global players are faced with complex situations for management decisions. In the focus of production industries, the determination of products, orders and machines on the current and potential future sites make network decisions already hard to overview. The increasing amount of influencing factors in a more and more restricted time frame for managers in charge leads to a multidimensional complex

decision. Until now, production networks are mainly cost optimized, to limit the decision to one of the most important dimensions for network configurations.

In this paper, we present an approach to support the decision process for the complex problem of designing global production networks by defining a judging system to analyze the risk of a certain production network configuration.

1.2. Motivation

Within an industry based project the global production network of a German mid-sized company operating production sites in the automation industry in Asia, Europe and North and South America was analyzed and optimized with respect to the cost dimension. The minimization of costs that depend on a tremendous number of design options taking into regard all product groups and their production processes which need to be allocated to the amount of existing or new production sites.

In this decision managers are generally confronted with an enormous complexity caused by the huge number of variables implicated by design options that spread out a solution space that cannot be handled by simple calculations or instinctive decisions. Thus, large production networks generate solution spaces that quickly reach values of the order of 10 to the power of 4700, which exceeds the number of atoms in our universe by far. [1]

Examples show that especially risk averse companies should consider total or partial blackouts of production sites to avoid enormous financial consequences. External risks can be relevant to every company operating in countries over the globe. Geographical and political instability can have an impact on production processes. For example, Japanese car builders Toyota, Nissan and Honda had to suffer serious losses in production in the aftermath of the tsunami in 2011[2] and political riots forced GM to close sites in Egypt in 2013.[3] Further examples include the flood in Germany[4] as well as confiscations of factories in China, due to the political situation, causing dramatic losses. [5] These examples bolster the fears of the companies and strengthen the request to include a strategic risk dimension to their global production network decisions.

Hence, managers are challenged in their decisions regarding the network design by knowing the risks which are aligned within a global production and by managing their effects. As the examples from above show, they have to take in regard country specific risks with their effect on the production and they have to be able to benchmark several scenarios relatively to each other. Finding a network design with not just the lowest costs but also the most adequate level of risk, should have first priority.

The productivity of a global production network is caused by the functionality of each production site which premises steady political circumstances and the integrity of the used manufacturing sites in every particular production country.

The purposes of a decision situation, which is impossible to overview, with a need for a decision in a short time, is the main problem of a decision making process regarding production network configurations. Finally, a compact decision basis for managers in charge is needed to allow an understanding and overview of the decision in a short amount of time in the dimensions of cost and risk.

2. Requirements

This paper is divided into two parts in order to implement the risk management into the analysis of production network

configurations. The first part is dedicated to the measurement of political and geographical risks, which directly leads to a potential blackout of production sites. For this purpose, the paper introduces a methodology to scale these risks from 1 (very low risk) to 6 (very high risk). The Geographical Risk Score (GRS) and the Political Risk Score (PRS) were aggregated to the Overall Risk Score (ORS), whose value gives indication about the feasibility of occurrence of partial or total blackout of production sites within the global production network design.

The second part includes the measurement of extent of loss in case of partial or total blackouts of production sites caused by geographical hazards and/ or political risks. Therefore, the extent of loss is equally scaled from 1 (low impact) to 6 (total production blackout of the network) within the Extent of Loss Scale (ELS). Depending on how resources, technology and know-how are spread over the company's global production network, this value gives indication about the impact of potential blackouts.

On the basis of these two parts, the integration of this methodology into an existing tool, developed by the Laboratory for Machine Tools and Production Engineering (WZL) at RWTH Aachen University, allows an efficient and entirely software supported risk analysis of global production networks. The synthesizing visual overview gives valid information about the risk of specific configurations by comparing a set of configuration scenarios and makes global footprint design decisions even more efficient.

3. State of the art

The paper's aim is the integration of risk analysis in the design process of global production networks. A holistic benchmark of such a design process has to consider costs, complexity and risk as the 3 Dimensions of Global Footprint Design. Thus, the following analysis of existing approaches contains the three mentioned scopes of network design and shows the state of the art in cost, complexity and risk orientated design of global production networks.

3.1. Approaches to cost orientated design of global production networks

Gathering the costs of a production network configuration, the Laboratory for Machine Tools and Production Engineering (WZL) at RWTH Aachen University published an approach, which refers to a software tool called OptiWo. This tool enables the calculation of a cost reduced network design with regard to the specific production and network variables. The software simulates parts of the process chain responsible for the production of a product. Transportation of the product or sub products can be included into the simulation. The software will then optimize the global production network by calculating the total landed costs for different configuration scenarios. This approach allows comparison of several scenarios to each other with regard to the specific costs of its network configuration. [1]

The acquired information is then presented with the help of interactive visualization tools in the data viewer. These visualizations are needed to support managers in their decision making process. Managers are faced with 250 decision per week, while more than 50% of them have to be done in less than 9 minutes. [6]

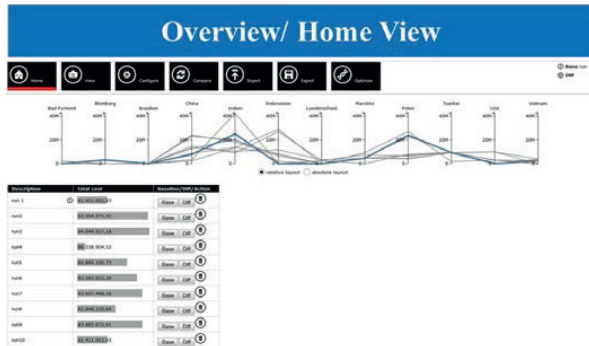


Fig. 1 Overview/ Home view [7]

Figure 1 shows the home view interface. It gives an overview about all calculation runs and displays the total landed costs per site in the upper graph. Every line in the graph is one optimization run. The lower graph displays all optimization runs with their summed total landed cost over all sites. The other buttons are used for the tool navigation. The visualization tools include a so called resource tree map and a process tube map, as shown in Figure 2 and 3.

The resource tree map is used to either overview all site sizes by resource capacity or area, or to visualize a selection of production sites with the located resources and their utilization. It is also possible to interactively search for resources or production sites and highlight them.

The sizes of the rectangular areas in the tree map illustrate the resource capacity or the area used for different resources. The example in Figure 2 shows a site with several resources, which occupy different sized areas within the site. The utilization of each technology is shown by a color code. The color varies from red (low utilization: 0%) to green (high utilization: 100%).

The tube map is used to visualize the process chain of the production of a product. The colors depict different locations. A “station” illustrates a process step. A “change-station” shows assemblies.

Figure 3 shows a production process which has process steps in different locations. The three green lines depict different process steps which are located at the same production site. The purple line represents a process taking place at another production site. At the “change station” the sub products are then assembled to the final product which is transported to the customer. Again, the assembly takes place at a different location.

With these innovative visualization tools managers are able to quickly analyze the complex decision situation and overview the given footprint intuitive to handle the decision making processes efficiently. [7]

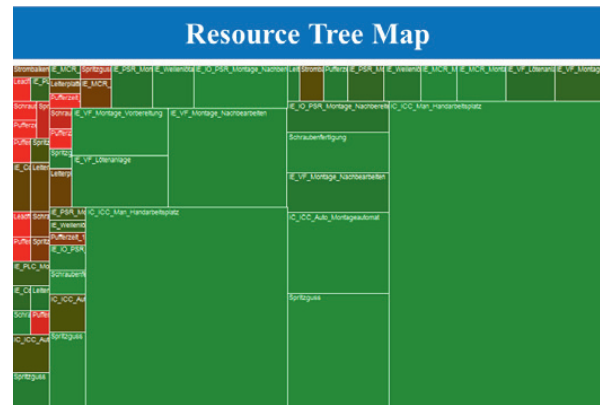


Fig. 2 Resource tree map [7]

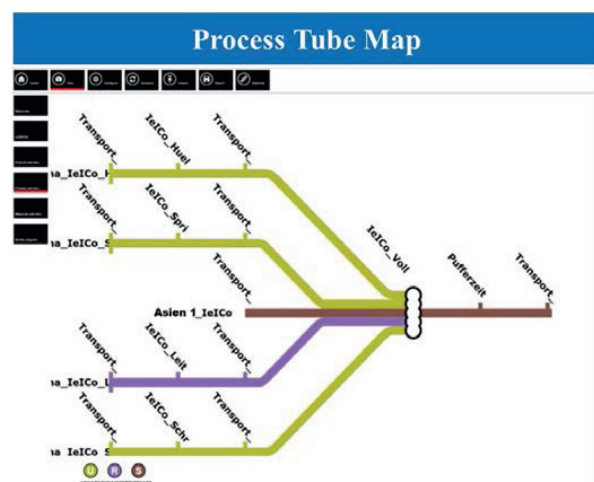


Fig. 3 Process tube map [7]

3.2. Approaches to complexity orientated design of global production networks

Extending the approach to cost orientated production network design the Laboratory for Machine Tools and Production Engineering (WZL) at RWTH Aachen University published a concept for complexity management in production networks. This approach focuses on complexity-oriented optimization of production networks by using an algorithm that calculates complexity indicators for different network configuration scenarios iteratively. Therefore, complexity, defined as plurality and diversity, is determined with regard to production network specifics on several levels including complexity drivers such as number of product groups, employees, production sites and the number of interfaces between these sites. [8] The starting point for such an algorithm is the current network configuration defined by OptiWo. Implying the mentioned complexity drivers, the algorithm calculates a complexity indicator for this configuration. Selective changes of the configuration aiming at the reduction of the amount of complexity in the production network will lead to the configuration with the minimal

complexity indicator by an iterative process. By doing this, this approach detects the complexity optimal design for the current network under given boundary conditions.[9]

3.3. Approaches to a risk orientated design of global production networks

The core element of this paper is the integration of risk analysis in the design process of global production networks. In general, risk is defined as an ‘occurrence, that is gratuitous because of its negative effect on the company’.[10] Analysis of identified risks regard on one hand the feasibility of occurrence and on the other hand the extent of loss.[12] The traditional way of a risk analysis leads to a risk-map, as shown in Figure 4. In this visualization the feasibility of occurrence and the extent of loss are plotted for each business case. The best case is in the lower left corner. Business cases in the upper right corner are the most risky ones with a high feasibility of occurrence as well as a high extent of loss. These cases should be avoided.

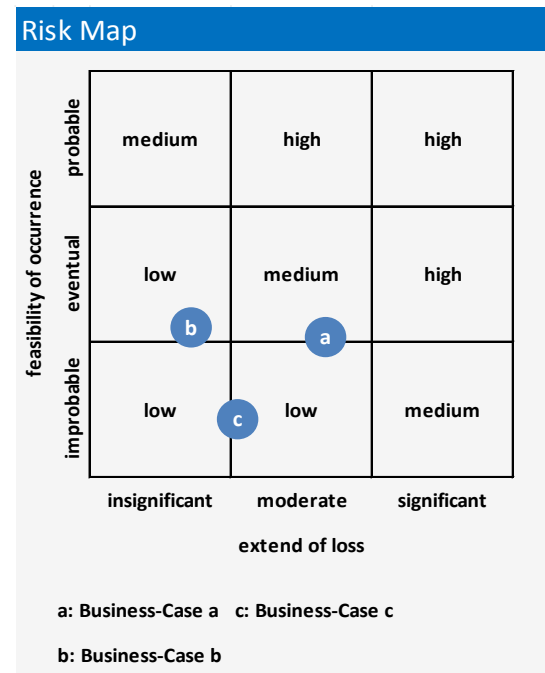
The essential component of an adequate risk management in global production networks is the identification of the network specific risks.

HALLIKAS defines production networks as networks of cooperating but independent companies in sense of a supply chain which deals final and semi-final products with each other along the value chain. Risks, which do exist in this perspective, are in the intersections of inter-companies’ cooperation.[11]

THOM ensues this definition of production networks and determines production network risks as logistical risks in procurement and sales as well as risks in the production and companies’ system during internal value creation. THOM is aware of the existence of external risks like geographical or political that can have an ‘outspreading effect on the companies’ production network’.[9] but does not concern them further because of their ‘spontaneous and unpredictable character’. Companies can just react or completely deny commercial activities that could be effected by those external risks.[10]

KOENIG identifies four groups of risks effecting companies producing in global networks and defines the machinery, material, employees and production hold ups caused by supplier problems. External risks, as geographical and political, are stated as relevant to global producing companies but are unattended by KOENIG, because they were ‘not verifiable by internal actions in production technique’.[12]

CHOPRA identifies risks for global supply-chain breakdowns and their drivers. With identifying migration strategies to influence the defined risks, CHOPRA allows managers to react on potential risks for supply chains. This approach bases on a qualitative analysis and supports managers with a recommendation on prioritizing supply chain risks by stress testing. The main risks can be reduced by tailoring a migration strategy for the individual supply chain of the company. [13]



ig. 4 Risk map [10]

3.4. Research Question

In summary, a demand in identifying and managing the production network specific strategic risks exists. The question arises, how risks of a global production network can be analyzed and how a classification system for risk assessment can be integrated automatically into the existing analysis of the costs of a global production network.

4. Risk analysis procedure

The risk of a production network is composed of two aspects. First, the feasibility of occurrence of geographical and political risks at one location which cause a complete or partial blackout of the production site and second, the extent of loss due to the blackout which is depending on the distribution of manufacturing expertise and resource redundancies within the production network.

Risk-averse companies have to endeavor the minimization of financial consequences caused by political and geographical risks in the several countries of their production sites to achieve the optimal production footprint.

4.1. Feasibility of occurrence

For the analysis of geographical and political risks all events that could cause a total or partial failure of one or more production sites are taken into account. The data for this evaluation was allocated from leading institutions in risk analysis.

4.1.1. Geographical Risks Score (GRS)

In order to analyze the geographical risk several indicators from the United Nations World Risk Report were consulted.[14]

These include the endangerment due to geographical threats such as floods, earthquakes, drought or the rising of the sea level. Additionally, the report evaluates the coping capacities of a region. From this data, two factors are determined and multiplied to generate an overall geographical risk score. The exact calculation process is shown in Fig. 5.

Endangerment	Coping Capacities
A earthquakes B hurricanes C floods D droughts E rising of the sea level	A awareness of corruption B quality of crisis provision and early warning systems C physicians per 10.000 inhabitants D hospital beds per 10.000 inhabitants E quality of insurance (except life insurance)
1.0 × people effected by A, B, C	0.45 × 0.5 A + 0.5 B
+ 0.5 × people effected by D, E	+ 0.45 × 0.5 C + 0.5 D
+ 1.0 × population size	+ 0.1 × E
Geographical Risk Score	Endangerment x Coping Capacities

Fig. 5 Calculation process according to UN World Risk Report [14]

4.1.2. Political Risks Score (PRS)

Such as the geographical risks, the evaluation of political risks is based on the research of leading institutions. To increase validity and to reduce deviations, a weighted average value was calculated over the data of two institutions. This value is taken as the Political Risk Score.

In this calculation only the factors “exercise of influence by governments” and “political violence” were regarded. These include the economic influence by the government, which lead to disadvantages for foreign business proceedings and the probability of strikes, civil war, terrorism and alike.

Having evaluated both risk scores an Overall Risk Score (ORS) is determined by calculating a weighted average value over the two described risk scores. As political risks are expected to be more likely to occur and to be the greater threat to the production network, the Political Risk Score is weighted higher than the Geographical Risk Score (GRS).

The Overall Risk Score is ordinal scaled (1 very low risk; 6 very high risk of a site blackout) due to the structure of the used data, allowing to rank the different footprint designs produced by the OptiWo tool in order. However, the Risk Score cannot be used to make a statement about the relative degree of distance between the footprints.

4.2. Extent of Loss Score (ELS)

The extent of impact on the network due to a blackout because of geographical hazards and/ or political risks depends on how resources and technology as well as know-how is spread over the global production network of a company. Consequently, footprint designs with the same Overall Risk Score have to be rated differently when having different distributions of manufacturing expertise and

resource redundancies. For both values calculation formulas were developed at WZL which consider the impact of the distribution of the above mentioned. Conventionalized equations are given below:

Raw Expertise Value (EV)

$$= \frac{1}{n} \sum_{i=1}^n \frac{\sum \text{of process steps of product } n \text{ at the site}}{\sum \text{of process steps of product } n \text{ in the network}}$$

Raw Resource Redundancies Value (RRV)

$$= \frac{1}{n} \sum_{i=1}^n \frac{\sum \text{of machines of Type } n \text{ at the site}}{\sum \text{of machines of Type } n \text{ in the network}}$$

The Raw EV and RRV are standardized to a one to six scale to get EV and RRV. These values are combined with a weighted average value to the Extent of Loss Score (ELS). Having calculated the ELS and ORS, it is now possible to give a full analysis of the footprint design risk which is presented in a portfolio diagram.

Fig. 6 shows the risk portfolio diagram which was created with data from the industry project mentioned before. Each circle represents one optimization run of the OptiWo tool. To analyze the effect of different network configurations on the Overall Risk Score (ORS) and the Extent of Loss Score (ELS) different scenarios with certain restrictions for the OptiWo tool were created. Four typical network strategies were used for this validation. Due to the fact that the algorithm does not find the global optimum, but a very good solution in a reasonable time, a couple of runs for each scenario are optimized to identify the best network configuration. Fig. 6 shows the three most interesting runs of each scenario.

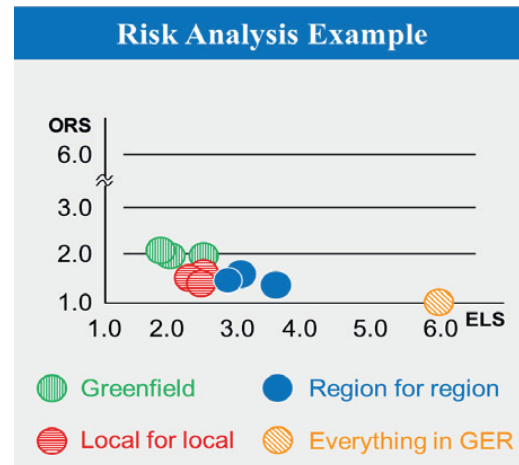


Fig. 6 Risk portfolio diagram

The logical expectation that a scenario in which the company produces every product in one site in Germany leads to the lowest ORS but also to the highest ELS value, is approved by this data.

Compared to scenario 3 (Local for local), in which every product is produced where it is sold, the ELS value for scenario 4 (Everything in Germany) is higher, which one

would have also expected beforehand. In this scenario the ORS is the calculated value for Germany based on geographical and political risks, because no other site is used. The ELS is rated with the highest value, because a blackout of the one single site shuts down the total production in the production network.

In case of a greenfield scenario, where the algorithm is only restricted to the offered site positions on the globe, products and processes become distributed for a cost optimized configuration. In this case the risk dimension decreases in terms of ELS value, but increases in ORS dimension. This influence of a greenfield optimization is taking place, because the cost optimization includes the transport costs, which leads to a distribution of the production volume to sites around the world. On the other hand, the algorithm chooses the sites with the best cost structure. These are mainly countries with lower political stability and a higher risk on ORS side.

The other two scenarios lie between the extreme scenarios concerning the risk as well as they show clusters in ORS and ELS levels. This fact that running several optimizations with the same scenario restrictions leads to very similar results for the ORS and ELS value validates the functionality of the risk analysis procedure.

5. Potential of the Risk Analysis System

The approach to risk analysis described in this paper is able to add a risk dimension to the decision making basis for management in charge of global production network decisions. Keeping the dimensions distinct allows managers to find a decision which fits to the risk cost ratio their company aims for.

The next step in the development of the system is to enlarge the view on ELS value on more than the viewed aspects of product and resource basis. Furthermore, the Laboratory for Machine Tools and Production Engineering is implementing the risk analysis system in the existing OptiWo tool. After the optimization on cost dimension, the “viewer” will fully automatically add the risk dimension to the decision basis. Therefore, it is planned to add intuitive visualizations to work with the risk dimension like with the cost dimension. The data for the ORS value will be implemented by a web interface to a data service. In this way, it is possible to work with up-to-date data. Finally, it will be possible to analyze the dependency between cost and risk of global productions networks, by analyzing a multitude of network designs. With a methodology to integrate the risk dimension into the optimization algorithm of the tool, the decision making basis for managers can efficiently be customized to the managers risk disposition.

With the use of this overall approach, the algorithm will directly optimize the network to the individual risk cost decision preference of the company.

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